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GB A 2103830 GB A 2027925
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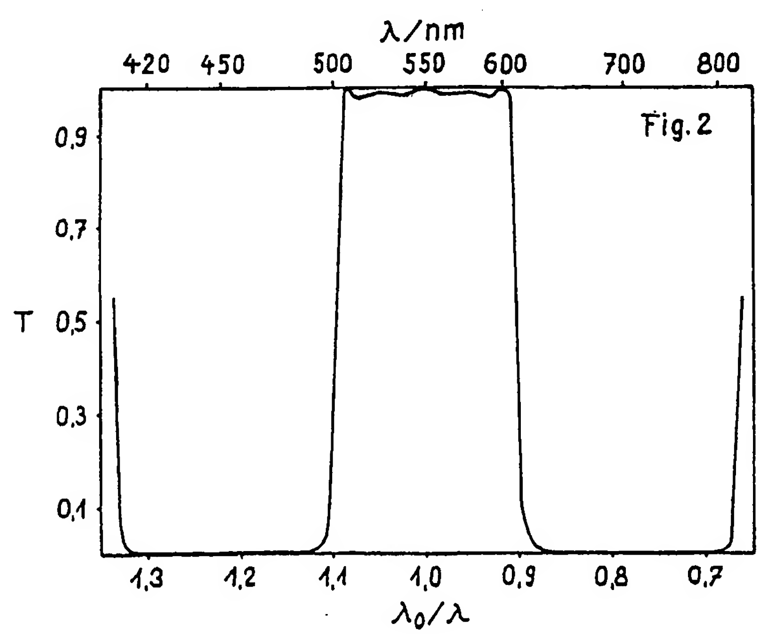
(58) Field of search
G2J

(54) Interference Filter with a Pass Band

(57) An interference filter having a pass band, comprises on a light-permeable support several filter layer groups, e.g. having a layer structure g2H, Hg2NH, HNg2HNH or HNHg2NHNH, placed on one another in a symmetrical arrangement, which groups are respectively connected by an intermediate layer N, wherein the light-permeable nonmetallic individual layers H, N or g2N of the filter layer groups have different indices of refraction n_N and n_H and an optical layer thickness of 1/4 of the central filter wave length λ_o or an integral multiple g, wherein g is 1, 2 or 3, of the double value of 1/4 λ_o, in one or more outer filter layer groups the number of the individual layers being reduced by the outer individual layers H or N with respect to the number of the individual layers in one or more internal filter layer groups and/or in one or more outer filter layer groups the optical layer thickness of the respective individual central layer g2H or g2N being lower than the optical thickness of the respective individual central layer in one or more internal filter layer groups.



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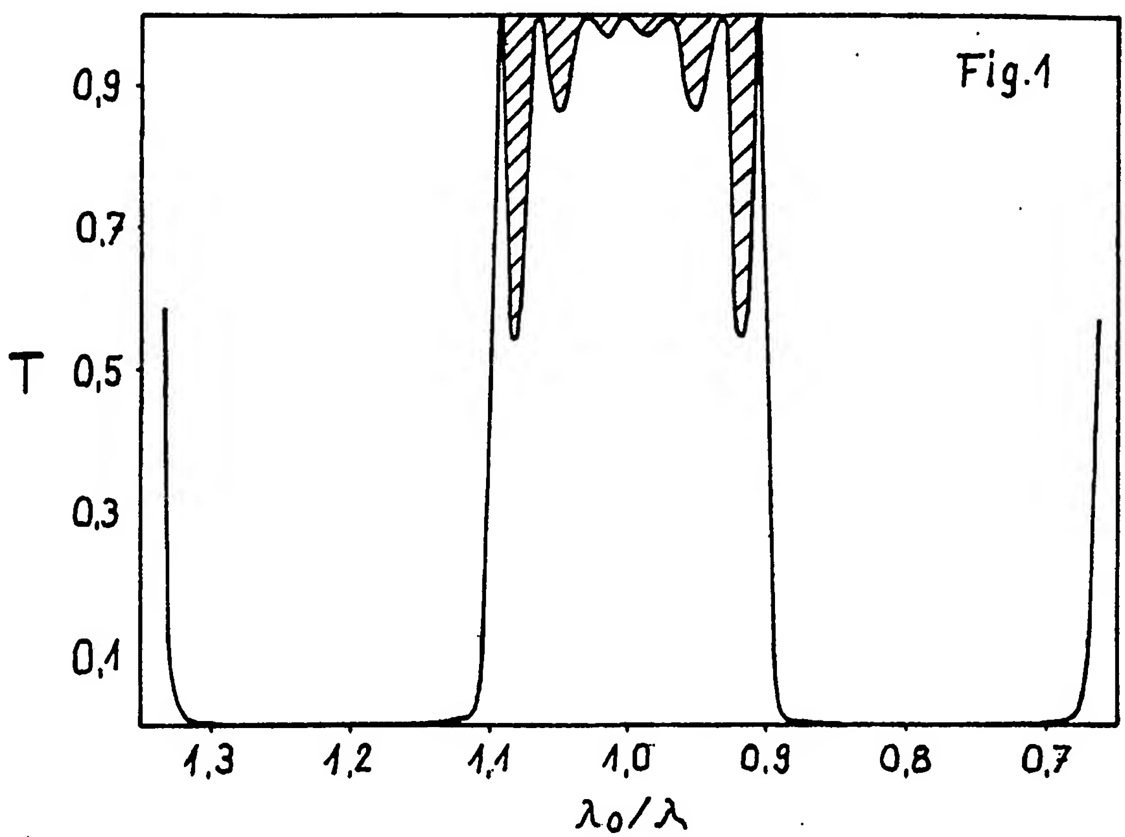
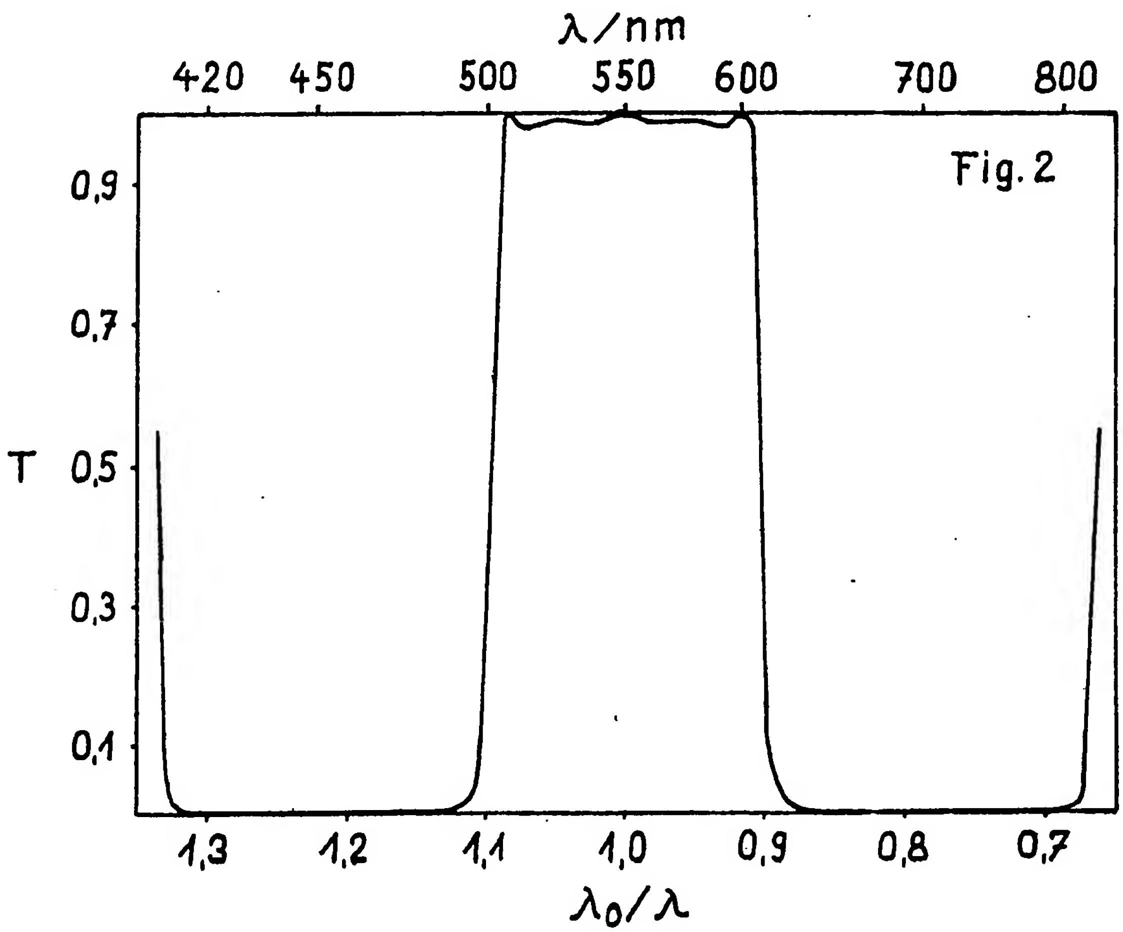


Fig.1
T
0,9
0,7
0,5
0,3
0,1
1,3
1,2
1,1
1,0
0,9
0,8
0,7
λ_0/λ


λ/nm
420
450
500
550
600
700
800
Fig. 2
T
0,9
0,7
0,5
0,3
0,1
1,3
1,2
1,1
1,0
0,9
0,8
0,7
λ_0/λ

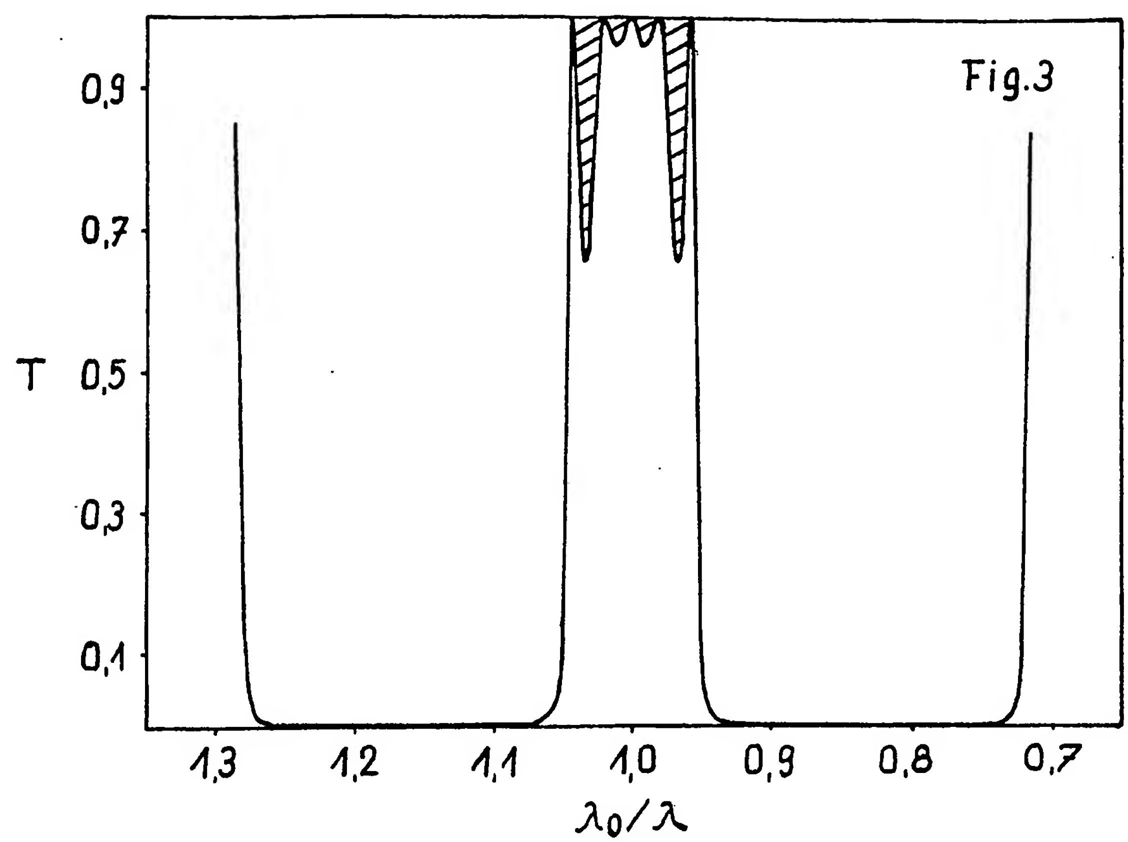
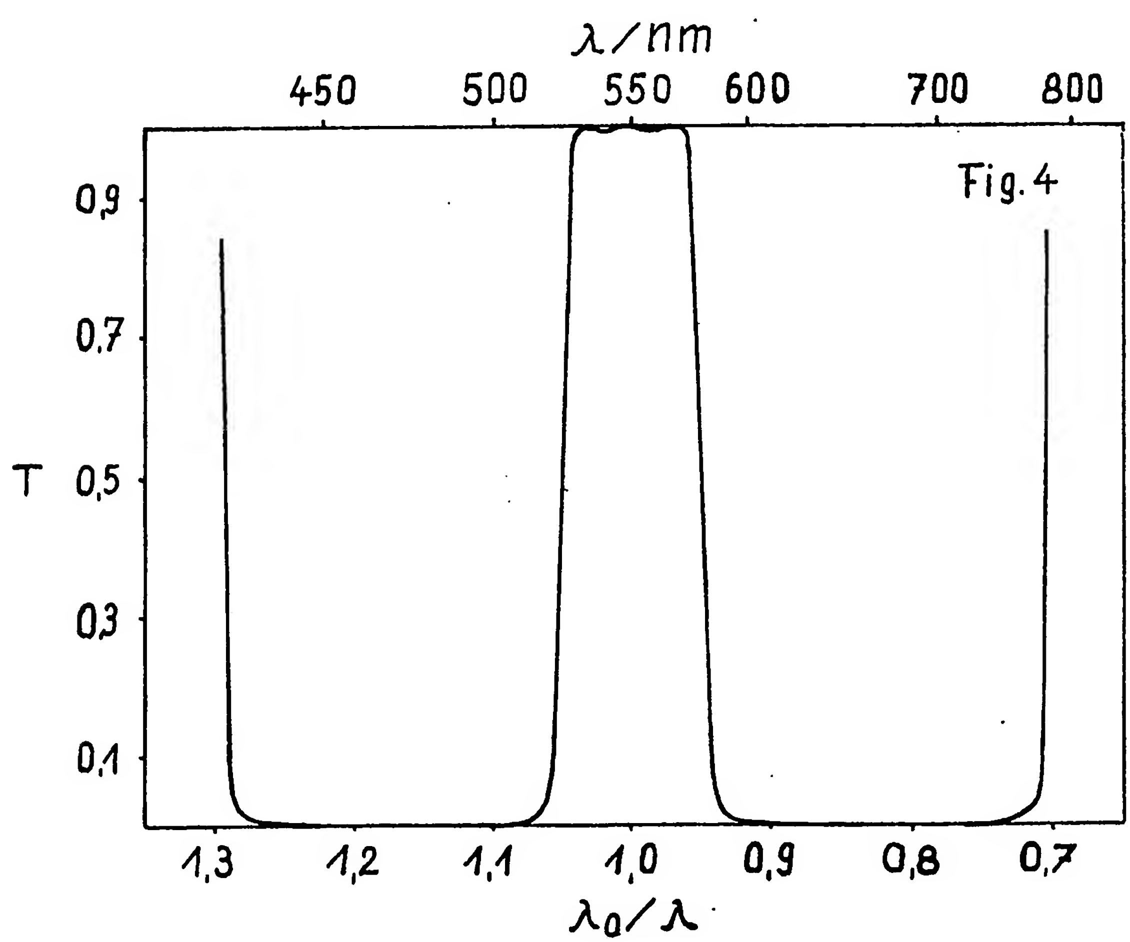


Fig.3
T
0,9
0,7
0,5
0,3
0,1
1,3
1,2
1,1
1,0
0,9
0,8
0,7
λ0/λ


λ/nm
450
500
550
600
700
800
Fig.4
T
0,9
0,7
0,5
0,3
0,1
1,3
1,2
1,1
1,0
0,9
0,8
0,7
λ0/λ

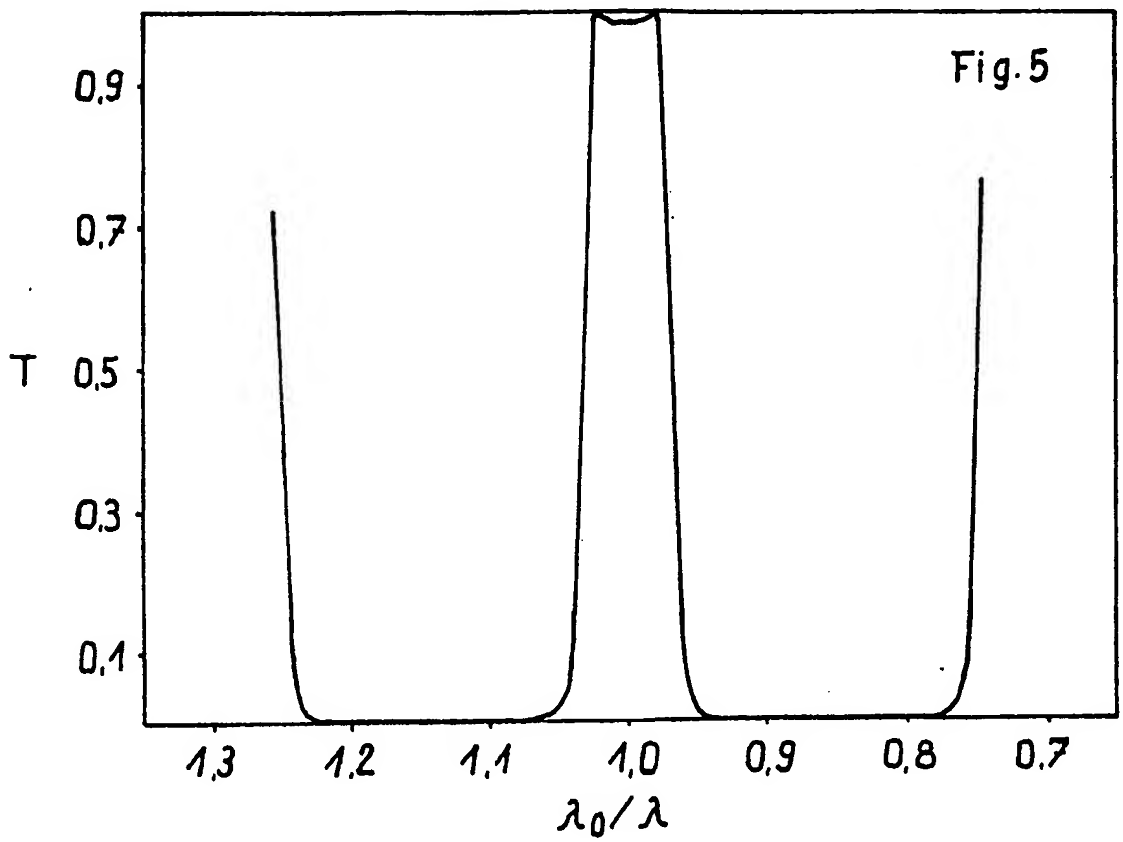
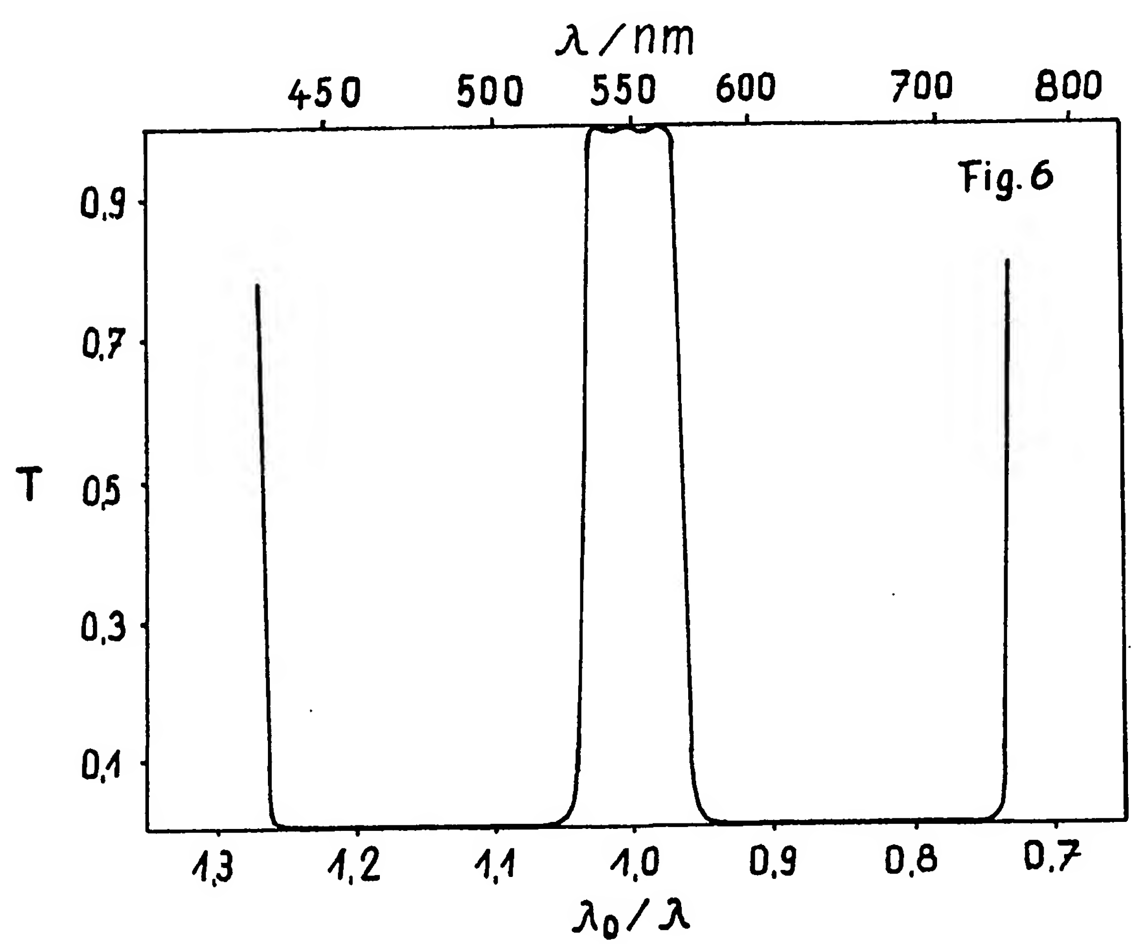


Fig.5
T
0,9
0,7
0,5
0,3
0,1
1,3
1,2
1,1
1,0
0,9
0,8
0,7
λ_0/λ


λ/nm
450
500
550
600
700
800
Fig.6
T
0,9
0,7
0,5
0,3
0,1
1,3
1,2
1,1
1,0
0,9
0,8
0,7
λ_0/λ

SPECIFICATION

Interference Filter with a Pass Band

This invention relates to an interference filter with a pass band of band width from 3% to 30% of the central wave length of the said pass band.

Such filters are used for the selection of limited spectral areas and are therefore used in optical arrangements and appliances for the ultraviolet, visible and near infra red ranges in the electromagnetic spectrum.

It is known to provide interference filters with a pass band that consist of a layer arrangement with metallic and non-metallic or solely non-metallic layers, that are disposed on top of one another on a light-permeable substrate and are generally protected against external effects by a cover glass cemented thereon, possibly with an additional block filter function.

Interference filters with light-permeable metallic and non-metallic layers are known from German Patent Specification 716 153. These filters have the drawback that the transmission is greatly decreased in the pass band area by a high absorption of light into the metal layers. The W. German Patent Specification 913 005 discloses interference filters consisting of light-permeable, non-metallic layers whose refraction is alternately high and low. Since the non-metallic layers have a low absorption, these filters have a very high maximum transmission in the pass band area. However, it is disadvantageous, in many applications, for the area of high transmission to remain limited to a narrow band of wave lengths.

A structural widening of the band pass width of such a filter by reducing the number of layers leads to a light permeability in the stop bands which is inadmissibly high for the purposes of use and to a worsening of the slope of the edges of the spectrum limiting the pass band.

The periodic series connection of a plurality of identical such filter elements with a small number of layers and consequently a widened band pass width provides the so-called "multiple cavity filter" which has a low light permeability in the stop bands and a wide band pass area which is steeply limited from a spectral point of view. (Z. Knittl, *Optics of Thin Film*, John Wiley & Sons, London-New York (1974)).

These filters, however, have an essential drawback in the case of the necessary series connection of more than three filter elements, that is to say an absorption band structure is produced in the filter pass band that causes a reduction in transmission. In addition, this band structure reacts in an abnormally sensitive manner to layer thickness defects produced during manufacture.

In addition, it is known to produce interference filters having a pass band in such a way that a filter with a wide short-wave pass band area is combined with a second filter having a wide long-wave pass band area such that the overlapping pass band areas of the two filters limit a band of wave lengths. (H. A. MacLeod, *Thin-Film Optical Filters*, Adam Hilger Ltd., London, (1969) p. 154 ff).

A reference to the above arrangement is also contained in the East German Patent Specification 6369.

Interference filters constructed in this way to filter out a spectral pass band area have the drawback that two different filters having different layer arrangements are required for their production which leads, consequently, to an increased technical complexity. In addition, the spectral accuracy is unsatisfactory as a result of the superimposition of the manufacturing defects of two filters.

It is the aim of the present invention to increase the quality of optical interference filters having a pass band and to remove the drawbacks referred to above.

Further the present invention seeks to provide an optical interference filter with a band pass that enables a high transmission by removing, as far as possible, the band structures in the filter pass band without, in this respect, impairing the advantageous properties of the filter, such as the corresponding band width of the pass band and the good suppression effect in the lateral stop bands.

According to the present invention there is provided an interference filter having a pass band, comprising an interference layer arrangement that is disposed on a light-permeable support and which may be closed by a cover glass cemented thereon and which is composed of several filter layer groups, for example having a layer structure g2H, Hg2NH, HNg2HNH or HNHg2NHNH, placed on one another in a symmetrical arrangement, which groups are respectively connected by an intermediate layer N, wherein the light-permeable non-metallic individual layers H, N or g2H, g2N of the filter layer groups have different indices of refraction n_N and n_H and an optical layer thickness of 1/4 of the central filter wave length λ_o or an integral multiple g, wherein g is 1, 2 or 3, of the double value of 1/4 λ_o, characterised in that in one or more outer filter layer groups of the interference layer arrangement the number of the individual layers is reduced by the outer individual layers H or N with respect to the number of the individual layers in one or more internal filter layer groups and/or in that in one or more outer filter layer groups of the interference layer arrangement the optical layer thickness of the respective individual central layer g2H or g2N is lower than the optical thickness of the respective individual central layer in one or more internal filter layer groups.

In this respect it is advantageous if the individual layers N or g2N have a lower index of refraction with respect to the individual layers H or g2H.

It is also possible, however, for the individual layers N or g2N to have a higher index of refraction with respect to the individual layers H or g2H.

In addition, it is advantageous for the index of refraction n_N of the intermediate layer N to conform to the index of refraction n_T of the support and, in the case of a cemented cover glass, to the index of refraction n_K of the cover glass cement.

If, however, the intermediate layer N, the support and the cover glass cement have different indices of refraction, an additional intermediate layer N may be placed between the support and the interference layer arrangement and/or between the interference layer arrangement and the cover glass which may be cemented thereon.

The essential feature of the invention consists in that in the interference layer arrangement of the interference filter of the invention at least one external filter layer group differs from one internal or from several internal filter layer groups of identical layer structure with respect to the number of individual layers H or N or the optical thickness of the individual central layer or may differ with respect to both the above features.

In effect the number of individual layers H or N or the optical thickness of the individual central layer g2H or g2N should be lower in at least one external filter layer group than in one or more internal filter layer groups.

The external filter layer groups are understood to be the lowermost group disposed on the support and the uppermost group facing the external medium, i.e. a cover glass, although this may additionally relate, for example, to the second lowermost and the second uppermost filter layer groups etc.

It is advantageous if the external filter layer groups are reduced with respect to the internal filter layer groups of identical layer structure solely in each case by the two outer $\lambda_0/4$ individual layers H or N of these filter layer groups or if the individual central layer g2H or g2N of the external filter layer groups is reduced by 2H or 2N layers and therefore by $\lambda_0/2$ in its optical thickness with respect to the internal filter layer groups.

The advantage of the interference layer arrangement of the invention consists in that the perturbing band structures in the filter pass band area are removed or greatly limited leading to a higher transmission. The other filter properties, such as the band width and the suppression effect in the lateral stop bands are for the most part retained.

Conventional glass plates or known filter glasses, with which additional filter effects which are known *per se* are achieved, may be used as layer supports and cover glasses.

The invention will be more fully understood from the following description given by way of example only with reference to the several figures of the accompanying drawings in which:—

Figures 1 and 3 show, for the purposes of comparison, the spectral transmission T for an interference filter having a layer arrangement according to the prior art, and

Figures 2, 4, 5 and 6 show the spectral transmission T of the interference filters of the present invention described in Examples 1, 2, 3 and 4.

The spectral representations were taken in the wave numbers λ_0/λ and are related in each case to the central filter wave length λ_0 of the filter pass band area which may be selected to have any value and simultaneously acts as the measurement wave length for the individual layers, as H and N are layers having an optical layer thickness of 1/4 λ_0.

After the determination of a desired wave length λ_0 for the central filter wave length which is adapted to the respective purpose of use, the wave length spectrum and the optical thickness of each individual layer are also determined.

In Figures 2, 4 and 6 the wave length scale for the case in which λ_0 is 550 nm is shown, for purposes of illustration. In this particular case all the individual layers H and N have an optical thickness of 1/4 λ_0 that is 137.5 nm and the individual central layers g2H and g2N have an optical thickness which is greater by the factor 2g, wherein the value 2g (where g is a whole number) is given in each of the following four examples.

EXAMPLE 1

Embodiment 1 makes use of an interference filter having a known layer arrangement and containing defects, which arrangement has been modified in accordance with the invention.

The known layer arrangement consists of seven identical filter layer groups having a structure G_2=H2NH, which are placed on one another on a glass support, are connected by N layers and protected by a cover glass cemented thereon. The layer system may be illustrated symbolically as follows:

Glass/$NG_2NG_2NG_2NG_2NG_2NG_2$-
NG_2N/Cemented glass.

In this respect N refers to individual layers or intermediate layers of cryolite having an index of refraction n_N of 1.30 and H refers to individual layers of zinc sulphide having an index of refraction n_H of 2.36. The optical layer thickness of the individual layers N and H is respectively 1/4 λ_0, and that of the individual central layers 2N (where g is unity) in the G_2 groups is 1/2 λ_0. The filter layer groups consisting of three individual layers consequently have in each case an optical layer thickness λ_0.

The spectral transmission of these known interference layer arrangements is shown in Figure 1 which also shows the defect of a band structure in the pass band which decreases below a value of spectral transmission (T) of 0.5.

This known arrangement is modified in accordance with the invention in that the outermost two of the seven filter layer groups G_2 of the layer arrangement are respectively replaced by the simplest layer group G_1=2H, which actually represents an individual layer having an optical layer thickness of 1/2 λ_0.

Consequently, the interference layer arrangement of the invention has the symbolic representation:

Glass/$NG_1NG_2NG_2NG_2NG_2NG_2NG_1N$/cemented glass

Figure 2 shows the spectral transmission of this interference layer arrangement.

It can be seen that in the case of the interference layer system of the invention, the perturbing band structure is for the most part eliminated, whereas the other filter properties, such as band width, suppression effect and the like are retained.

EXAMPLE 2

Taking the conditions described in Example 1 as a basis Example 2 makes use of a known interference layer system subject to a band structure having the symbolic representation:

Glass/$NG_3NG_3NG_3NG_3NG_3N$/cemented glass, which comprises five identical filter layer groups G_3=HN2HNH having five individual layers in each case.

The same layer materials are used as in Example 1.

Figure 3 shows the spectral transmission in this respect and the disadvantageous band structure in the filter band pass area.

In accordance with the invention, the two outer groups G_3 in this layer arrangement are replaced in each case by a group G_2=H2NH having three individual layers, in which the number of individual layers is again reduced by omitting the two outer individual layers (H) from G_3.

The new interference layer arrangement may be represented symbolically as follows:

Glass/$NG_2NG_3NG_3NG_3NG_2N$/cemented glass.

The higher spectral transmission of this arrangement in the filter pass band area is due to the suppression of the perturbing absorption bands, as can be seen from the filter curve of Figure 5.

EXAMPLE 3

In the same way as in Examples 1 and 2 above, use is made of a further interference filter of the invention having the symbolic representation:

Glass/$G_3NG_4NG_4G_3$/cemented glass, the interference layer arrangement of which consists of the two internal filter layer groups G_4=HN4HNH and the two outer filter layer groups G_3=HN2HNH and the respective individual layers N disposed therebetween using the layer materials described in Example 1.

In this case, in accordance with the invention, in the two outer filter layer groups G_3 the individual central layer 2H (where g is unity) has an optical thickness that is lower by the amount 1/2 λ_0 with respect to the respective individual central layer 4H (where g is two) of the internal groups G_4.

The filter curve of Figure 5 does not show in this respect any disadvantageous band structures in the filter pass band area.

EXAMPLE 4.

Using the same layer materials as in the preceding examples, use is made of an interference filter having the symbolic representation:

Glass/$G_3NG_3NG_5NG_3NG_3$/cemented glass.

The four outer filter layer groups G_3, wherein G_3=HN2HNH, comprise five individual layers in each case, whereas the inner layer group G_5, wherein G_5=HNH2NHNH, consists of seven individual layers.

The filter curve of this interference filter as shown in figure 6 shows no perturbing band structures in the filter pass band area.

CLAIMS

1. An interference filter having a pass band, comprising an interference layer arrangement that is disposed on a light-permeable support and which may be closed by a cover glass cemented thereon and which is composed of several filter layer groups, for example having a layer structure g2H, Hg2NH, HNg2HNH or HNHg2NHNH, placed on one another in a symmetrical arrangement, which groups are respectively connected by an intermediate layer N, wherein the light-permeable non-metallic individual layers H, N or g2N of the filter layer groups have different indices of refraction n_N and n_H and an optical layer thickness of 1/4 of the central filter wave length λ_0 or an integral multiple g, wherein g is 1, 2 or 3, of the double value of 1/4 λ_0, characterised in that in one or more outer filter layer groups of the interference layer arrangement the number of the individual layers is reduced by the outer individual layers H or N with respect to the number of the individual layers in one or more internal filter layer groups and/or in that in one or more outer filter layer groups of the interference layer arrangement the optical layer thickness of the respective individual central layer g2H or g2N is lower than the optical thickness of the respective individual central layer in one or more internal filter layer groups.

2. The interference filter as claimed in claim 1, wherein the individual layers N or g2N have a lower index of refraction than the individual layers H or g2H.

3. The interference filter as claimed in claim 1, wherein the individual layers N or g2N have a higher index of refraction than the individual layers H or g2H.

4. The interference filter as claimed in claim 1, wherein the index of refraction n_N of the intermediate layer N corresponds to the index of refraction n_T of the support and, in the case of a cemented cover glass, with the index of refraction n_K of the cover glass cement.

5. The interference filter as claimed in claim 1, wherein if the indices of refraction of the intermediate layers, the support and the cover glass cement are different, an additional intermediate layer N is placed between the support and the interference layer arrangement and/or between the interference layer

arrangement and the cover glass which may be cemented thereon.

6. An interference filter constructed and arranged substantially as hereinbefore described and as shown in Figures 2, 4, 5 and 6 of the accompanying drawings.

7. An interference filter constructed and arranged with particular reference to any one of the Examples set out hereinbefore.

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